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DEPARTMENT OF COMMERCE
BUREAU OF FISHERIES
UGH M. SMITH, Commissioner

PROGRESS IN BIOLOGICAL INQUIRIES

REPORT OF THE DIVISION OF SCIENTIFIC INQUIRY FOR THE FISCAL YEAR 1920

By R. E. COKER
Assistant in Charge

APPENDIX II TO THE REPORT OF THE U. S. COMMISSIONER OF FISHERIES FOR 1920

Bureau of Fisheries Document No. 896

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PROGRESS IN BIOLOGICAL INQUIRIES.

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By R. E. COKER,
Assistant in Charge.

INTRODUCTION.

There are times when it is worth while to inquire somewhat searchingly into the value of the varied activities of the Federal Government, to ask what good purposes are to be served through a particular governmental function. Clearly, such a time is upon us now, and it is appropriate, therefore, to prefix this report of progress with a brief statement suggestive of the purposes which the Bureau of Fisheries attempts to serve through the Division of Scientific Inquiry.

The direct and practical relation of scientific studies to the fishery industries is not always clearly understood. A successful industrial establishment depends no less upon the maintenance of the source of supply than upon the marketing of its product. The Division of Scientific Inquiry stands with reference to the fishery industries somewhat in the same relation as the supply department to a manufacturing concern: It does not produce the raw materials,[a] but it concerns itself with the problems of ultimate sources, of judicious exploitation, and of the means and conditions of maintenance or possible increase of supplies.

To be more concrete, an oyster industry is impossible without oysters, but it is now painfully evident to all concerned that, in northern waters at least, the continuance of a supply of oysters depends upon the solution of problems of scientific inquiry, the problem, for example, of the conditions of securing a set. The salmon industry ranks among the very first in the fisheries of the United States, yet in most waters we have witnessed a gradual decline in the abundance of salmon, and where such a decline is not manifest, as in the Columbia River, it is universally attributed to the measures of artificial propagation. The Bureau is therefore urged to investigate the conditions of success in maintaining the desired runs by artificial propagation, and to furnish that knowledge of the life history and migrations of salmon without which they can not be successfully protected and conserved. These are problems of scientific inquiry. The stock of whitefishes in the Great Lakes has been gradually depleted, but protective measures can not be most intelligently devised and enforced without knowledge of the life history, habits, and movements of the fish, and this can be gained only by the skillful application of the methods of science. Nearly all persons concerned in the great shrimp fisheries recently developed off the South Atlantic and Gulf Coasts view with concern the future maintenance of the supply. Can the shrimp be wisely protected or most judiciously exploited while we do not know when or where it breeds or why it appears here or there in greater or lesser abundance? Clearly scientific studies have a very practical relation to the perpetuation of such a fishery.

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[a] That in this case is a function of nature as assisted by fish-cultural operations.

Beyond a doubt, there is no one connected with the fishing industries who believes, with reference to the majority of the existing fisheries, that any of them will maintain its present importance in future time, except as the resources upon which it is based may be conserved by sensible measures of protection. And certainly no one concerned with the determination of protective measures would hesitate to say that we must know the fish (or shellfish) and its manner and conditions of life if we would successfully protect it.

It is, then, of direct and not indirect importance, of practical and not theoretical significance to the fisheries that we should study the fish and attempt to solve some of the many problems upon which depend the perpetuation of the resources and the development of the industries. The industries are founded absolutely upon the resources. The maintenance of the resources is conditioned upon the results of scientific inquiry. How shall depletion be prevented? To what extent can utilization be carried? What are the possibilities of propagation, the conditions, the results? What are the methods and conditions of protection? How can the natural environment be improved? How can disease be combated or unfavorable conditions of environment be changed? It is such questions as these that scientific inquiry must answer. The very statement of the purposes to be served renders unnecessary the presentation of argument for their pursuit. The merit of the service performed can best be determined from the report of its progress that follows, allowing, as one must, for the varied geographic and industrial interests to be served.

The Bureau does not, of course, fulfill all of its functions in scientific inquiry at any given time, but this report will serve to indicate the present scope of work, as well as the progress that is being made. It may be remarked finally that the activities of the fiscal year just closed were reduced as compared with that of previous years, and that further reduction will mark the year next to come, due to the loss in course of the last year of not a few of the men who contributed to the accomplishment of the year's work. What has been done is due to the loyal and efficient services of men who have labored without stint under conditions of discouragement. Acknowledgment is due no less to those who have left only under the impulsion of circumstances than to those who have found it possible to continue in service.

STUDIES OF FISHES.

ANATOMY OF THE SALMONS IN RELATION TO FISH CULTURE.

From time to time the Bureau has had reports of abnormal conditions of brood fish at its trout stations, such as the sterility of brood fish which have been used for several years. These conditions do not keep the hatcheries from having success in propagating fish, but they do make the output less and the cost more. They involve waste, and it will pay, therefore, to find and remove the cause. It has always been supposed and was seemingly established by published descriptions that the eggs of salmonidæ are passed into the abdominal cavity and thence discharged. Recently Dr. W. C. Kendall, scientific assistant, as the result of anatomical researches, discovered that the published descriptions were wrong as referring to the several species which have come under observation. He has found that the membrane by which the ovary is suspended enfolds it in such a manner that the mature eggs do not normally fall into the abdominal cavity but pass along a sort of trough formed by a continuation of the suspending and enfolding membrane of each ovary, which extends to a point not far from the outlet, where the two unite into a single trough attached to the upper surface of the intestine. It is also apparent from the conditions discovered that eggs which escape into the body cavity could not in any conceivably normal way be subsequently discharged. The escape of eggs into the abdominal chamber is then abnormal, and the common observation of eggs in this space may be presumed to result from the improper handling of fish in artificial spawning operations or in preparation for dissection.

It was suspected that the bad condition of brood trout at some fish-cultural stations may have been due to rough or careless handling during spawn taking. Examination of specimens sent in from several stations strengthened this suspicion. Dr. Kendall then proceeded to visit a fish-cultural station, observe carefully the operations of spawn taking, and make immediate examinations of the fish. The results of the observations made at one of the best stations, taken in connection with the studies just mentioned, indicate that the abnormal conditions referred to were probably due, not so much to careless spawn takers as to wrong practices. Improvements in method are required, though additional thought and study seem necessary before explicit directions can be given.

ATLANTIC SMELTS.

Dr. W. C. Kendall, with the aid of D. R. Crawford, is completing a monograph of the species of the smelts (Osmerus) of the Atlantic coast of North America. The smelts are abundant and widely distributed fish of small size, which are of value not only in the markets, but also in the water as a source of food for game and food fish of larger size. The studies pertain to the geographical distribution, life history, growth, habits, habitats, and importance, and to the conditions of conservation both of the marine and the fresh-water smelts. Particular attention is given to those of New England and to the "ice fish" of Lake Champlain. There are indications of local races of marine smelts, and some fresh waters appear to be inhabited each by a race or species, distinct not only from the marine smelt but also from smelts of other fresh waters. The variation in size attained in some of the fresh waters of Maine is remarkable. Some lakes are inhabited by two distinct sizes of mature smelts, each having well-defined breeding seasons and subsisting upon different kinds of food. In one lake the minimum size of the small smelt when mature is about 1½ inches and the maximum size of the large smelt 4 inches, while in another the minimum size of the small form at maturity is about 4 inches and the maximum size of the large form 15¾ inches. We have to do, it seems, either with different species or with distinct races; that is to be determined later.

DETERMINATION OF SPECIES AND RELATIONSHIPS IN THE SALMON FAMILY.

One of the obstacles to the best success in fish-cultural work is the great difficulty of distinguishing positively the species of trouts and salmon. To obtain the desired results in propagation and distribution of fish, it is necessary to know beyond a doubt what species is being propagated and planted, as well as what kinds are native to certain waters, and what have previously been introduced. Nevertheless there still exist among sportsmen, fish-culturists, and scientists varying and conflicting opinions regarding the identity and relationships of the species of Salmonidæ, notably in the case of the steelhead and rainbow, fish which are extensively propagated by Federal and State hatcheries.

The difficulty lies solely in the fact that sufficient technical work has not been done upon the structural examination and comparison of such fish in numbers and from varying localities. The bureau has, therefore, encouraged the prosecution of a thorough and critical study of the structure and relationships of the members of the important salmon family.

Dr. W. C. Kendall, scientific assistant and ichthyologist, has given much attention to the osteology (bony structure) of salmon, trout, and related fishes, which, with studies of scales, proves of much value in the determination of families, genera, and species. While verifying many of the statements of others, some new facts have been discovered.[a]

A paper which is in preparation, based upon a study of trout from various regions of the West and upon geological considerations, presents a scheme of origin and distribution of the trouts which offers a plausible explanation of their present distribution and throws light upon hitherto obscure problems of classification.

Another report nearing completion is believed to settle the much-discussed question of the specific identity or distinctness of the rainbow and steelhead trouts.[b]

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[a] It appears that the salmons, trouts, and chars form a family (Salmonidæ) distinct from the whitefishes and ciscoes (Coregonidæ), the latter being based upon the characters enunciated by Cope and given by later writers as the characters of a subfamily. It has not yet been decided whether or not the grayling should be regarded as a family (Thymallidæ, Gill) distinct from the whitefishes (Coregonidæ), in which Regan includes them. The separation of the Pacific coast salmons (Oncorhynchus) from the genus which embraces the Atlantic salmon and rainbow and steelhead trouts is definitely confirmed. The lake trout (Cristivomer) is found to be notably different from the brook trout (Salvelinus). The smelt family (Osmeridæ, Regan) should also stand as distinct from the Argentinidæ. The pelvic bones of *Argentina silus* are widely different from any other isospondylous fish examined.

[b] After a careful study of the fish from taxonomical, anatomical, and distributional evidence the conclusion is reached that there are at least two wild forms which have been confused under the names of rainbow and steelhead trouts. One is predominantly migratory (ascending fresh waters from the sea), the other predominantly a permanent fresh-water inhabitant. The name *Salmo irideus* was originally bestowed upon a small steelhead form, as was also *Salmo rivularis*. There is absolutely no doubt concerning the proper application of *Salmo gairdnerii* to the steelhead, as Richardson's description is that of a large Columbia River fish and not a small blueback salmon (*Oncorhynchus nerka*), as one writer has stated. Contrary to current descriptions, the steelhead has

THE WHITEFISHES AND THEIR RELATIVES.

For a long time the Bureau, the several State fishery authorities concerned, and the trade have felt the serious need of knowledge regarding the habits of the whitefishes, ciscoes, and so-called lake herrings of the Great Lakes. Yet up to the present time we have not had even that positive determination of the species which is an essential basis of an inquiry into migrations, propagation, and other habits. During the past two or three years Dr. Walter Koelz, general assistant, has been detailed to a comprehensive study of the whitefishes and their relatives in the Great Lakes, beginning in Lake Huron. During the past year he completed the field work and report based upon that lake.

His report, which represents a substantial advance in knowledge of these fishes, is based upon a collection of 3,000 specimens of Lake Huron Coregonines and on field data as to their breeding times and breeding places, geographic and depth distribution, and migrations. He has definitely distinguished and defined 10 forms—8 species and 2 subspecies—all of which are referred to the Linnaean genus *Coregonus*. Two new species are described and three subgenera are recognized (*Leucichthys*, *Coregonus*, *Prosopium*). The forms of one subgenus (Leucichthys) fall into two ecological groups: (1) the lake herrings (*artedi*, *manitoulinus*), and (2) the chubs (*alpenae*, *reighardi*, *johannae*, *nigripinnis*) and bloaters (*hoyi* and its variant *profundus*).

The lake herrings are taken in shallow water to a depth of 16 fathoms, rarely deeper. One of them (*artedi*) is known also to range the surface waters to a considerable distance from shore. They spawn in November in shallow water on sand and gravel. The chubs and bloaters are taken near the bottom in water 30 to 80 fathoms or deeper. They occur on mud or clay bottom and feed chiefly on species of crustacea and mollusca. The spawning season for the five species extends from late August to March.

The species of chubs and bloaters have definable but overlapping ranges as regards depth. Each form has its greatest density of population at the center of its bathymetric range, and this density diminishes toward the borders of its range.

The pilot, *Coregonus* (*Prosopium*) *quadrilateralis*, occurs usually along the shores to a depth of 20 fathoms. It breeds in November in shallow water on rock or gravel bottom. The whitefish, *Coregonus clupeaformis*, is also shore-loving, seldom occurring deeper than 20 fathoms. It spawns in November in shallow water on rock or gravel. It is not expected that the report will be offered for publication before the investigations in other lakes are completed.

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larger (fewer) scales than the rainbow, and there appear to be other though inconspicuous and concealed structural differences.

There is probably more than one species or race of rainbow trout, and possibly also of steelhead. However, the rainbow trout of fish culture is largely from McCloud River (Calif.) stock and should bear the name, not *Salmo irideus*, but *Salmo shasta*. The fish-cultural rainbow stock has been more or less affected by admixture of another form principally from Klamath River, which may be another form or species of rainbow or perhaps a steelhead. This admixture is clearly perceived in the appearance and structure of many specimens of the rainbow stock of some of the hatcheries. The steelhead stock has always, so far as known, been unadulterated *Salmo gairdnerii*, although in the distribution from hatcheries it is known that in some instances the two forms have been regarded as identical and distributed as rainbow trout. Pure *Salmo shasta* is distinguished from pure *Salmo gairdnerii* by the smaller scales of the former.

BIOLOGY OF THE PACIFIC SALMONS.

The salmon fisheries, very valuable in themselves, support a packing industry, the product of which is of still greater value. Speaking in terms of appropriate correctness, we may say that the salmon taken from the rivers and lakes of Pacific Coast States and Alaska now yield each year 6 pounds of highly nutritious meat food for each man, woman, and child in the United States and its possessions. We enjoy and esteem these valuable economic resources now, but it is a serious question if the generations to follow will derive like benefits from the same waters.

It is true that the salmon are not necessarily exhaustible like a mineral resource, but that they are by nature self-perpetuative, provided only that present and future utilization is rightly regulated and that artificial propagation is intelligently directed. The decline of the fishery in most of the waters of the Pacific coast is clear evidence that we are not yet properly meeting the requirements in propagation and regulation. The situation in Alaska waters, a relatively new field of exploitation, has already reached a stage which investigators assure us is critical and which may be but the beginning of an era of decline.

It becomes a high responsibility, then, that we find out what must be done, that we study the salmons until we know fully their life histories and habits and the conditions of the maintenance of the runs.

The investigations conducted by Prof. C. H. Gilbert and Mr. Henry O'Malley in Bristol Bay and other Alaska waters, through cooperation of the Divisions of Scientific Inquiry, Fish Culture, and Alaska Fisheries, are reported fully in "Alaska Fisheries and Fur Industries in 1919,"[a] and need not, therefore, be described in this connection.

In Pacific Coast States studies of salmon have been conducted primarily by Willis H. Rich, with particular attention to the life history of the chinook salmon of the Columbia River.

Considerable progress has been made in the study of the life history as based on scale analysis. The necessary foundation for this work was laid by studies conducted during previous years and published recently under the title, "The Early History and Seaward Migration of the Chinook Salmon in the Columbia and Sacramento Rivers."[b] Even with the data at hand, the accurate interpretation of the adult scales has proven an extremely difficult task, owing to the great diversity in the types of nuclear growth. As a result of the study of large series of scale photographs and the calculations of sizes at various ages of several hundred individuals, it has now become possible to interpret fairly accurately the age and early history from examination of the scales of adult fish. From investigations pursued in the various tributaries of the Columbia River, it is found that many contain distinguishable races, just as had previously been shown in the case of the sockeye. The study of the chinook salmon taken in the open ocean by trollers and purse seiners has progressed to the point where a preliminary report is in course of preparation.

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[a] Bower, Ward T.: Alaska Fisheries and Fur Industries in 1919. Appendix IX, Report, U. S. Commissioner of Fisheries, 1919. Washington, 1920.

[b] Rich, Willis H.: Early History and Seaward Migration of Chinook Salmon in the Columbia and Sacramento Rivers. Bulletin, U. S. Bureau of Fisheries, Vol. XXXVII, 1919–20, pp. 1–73. Washington, 1920.

Satisfactory returns are being obtained this year from one of the experiments in marking young chinook salmon at the hatcheries of the Columbia River. Some returns have been obtained from three other experiments, and it is possible that additional results may be obtained later this year.

Additional marking experiments have been started during the past year with particular reference to chinook fry and yearlings and yearling sockeyes. At the same time, and in cooperation with the State Fish and Game Commission of Oregon, a representative of the Bureau began last spring the tagging of adult steelhead in the Rogue River. A proposed study of the steelhead and chinooks in this stream has, for various reasons, been delayed.

HABITS OF FRESH-WATER FISHES.

Perhaps no papers published by the Bureau are of more service to fish culture, to angling, and to the utilization and conservation of fresh-water fishes than those which comprise the results of careful studies into the habits of useful fishes. The works of Dr. W. C. Kendall, Dr. A. S. Pearse, and Dr. Jacob Reighard fall naturally into this class. Recent studies by Dr. Kendall are referred to in another place. The results of Dr. Reighard's observations are to be given publication in other places.

Some results of Dr. Pearse's recent studies are embodied in two useful reports, of which one was published last year and the other of which is in press. They are entitled, respectively, "Habits of the Black Crappie in Inland Lakes of Wisconsin"[a] and "Habits of Yellow Perch in Wisconsin Lakes."[b] The observations, which have been extended to several lakes, are based upon numerous collections at various seasons, places, and depths, the tagging and recovery of individual fishes, studies of food and parasites, and various other considerations.

BREEDING HABITS OF THE PADDLEFISH.

During a considerable portion of the past two years Dr. A. D. Howard, field assistant, has conducted an inquiry into the breeding habits of the paddlefish, *Polyodon spathula*, a food fish of the Mississippi Basin, which attains a large size and which is of particular value because its eggs make a grade of caviar scarcely inferior to that of the sturgeon. This important fish is diminishing in numbers, but all attempts at artificial propagation and all previous investigations of the breeding habits of the species have been barren of practical results. The present investigation, which began in January, 1919, was made possible through the cooperation of the Conservation Department of Louisiana.

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[a] Pearse, A. S.: Habits of the Black Crappie in Inland Lakes of Wisconsin. Appendix III, Report, U. S. Commissioner of Fisheries, 1918, 16 pp. Washington, 1919.

[b] Pearse, A. S., and Henrietta Achtenberg: Habits of Yellow Perch in Wisconsin Lakes. Bulletin, U. S. Bureau of Fisheries, Vol. XXXVI, 1917-18, pp. 293-366. Washington, 1920.

Observations were first undertaken in White Lake, near the Gulf, where the Superintendent of Fisheries had previously conducted investigations of the spawning of paddlefish. Owing, however, to changes having occurred in the lake due, it was believed, in part to drought and removal of water from the lake for irrigation of rice fields and in part to overfishing, no paddlefish were obtained. The investigator then proceeded to Natchitoches and Red River Parishes, where better conditions were encountered both in the Red River and in the Oxbow Lakes adjacent to it. Here over 300 paddlefish were taken, of which 17 were mature females with eggs and 3 were mature males. No females with eggs free or running were found, but one spent female was taken April 2 and another April 11.

An experiment was made in retaining large paddlefish in a good-sized inclosure formed by placing fine-meshed wire netting across the mouth of an arm of a bayou. Although no results in propagation were obtained, it was demonstrated that paddlefish could be kept in such an inclosure for two or three months at least. It was found also that by tethering a paddlefish by a line 5 or 6 feet long to an empty gallon jug the fish could be kept in good condition and recovered at will.

It was observed that while large mature fish may be found in isolated lakes, young paddlefish are found only in those lakes or bayous which have a connection with the river. Nevertheless, it may be that paddlefish propagate successfully in isolated lakes of very large size, such as White Lake (in former years), where the chance of avoiding enemies is better. Fish retained in small pens or tied with a line were frequently attacked and killed by turtles, principally the soft-shell turtles. The turtle evidently sought the eggs, since this was the first part of the fish to be devoured, and turtles taken in the vicinity were observed with paddlefish eggs in mouths and stomachs.

In the spring of 1920 more attention was given to river fish than to those landlocked in lakes, but on account of flood conditions only a very small number were secured and none of these were mature males. While awaiting more favorable conditions, experiments were continued upon the lake fish, the eggs being treated by the artificial fecundation method successfully used with sturgeon. Eggs in sand remained free of fungus, but no development was observed in any of them. It is believed that success depends upon securing river fish (among which only have spent females been found), but a favorable season without too much high water is necessary for this.

LIFE HISTORIES OF MARINE FISHES.

One of the most important conditions of intelligent exploitation or protection of the great fisheries of the seas is a knowledge of the life histories of the species. Such knowledge is difficult to obtain, since it is manifestly impossible to observe directly the daily and seasonal movements of individual fish that possess the freedom of the sea. The desired knowledge can be accumulated but slowly through the pursuit of oceanographic studies and the continual collection of fishes under conditions of accurate record, with especial reference to eggs and larvæ. The material and the data accumulated at any one time may tell no useful story, but when there has been gradually gathered together a great store of materials, many of the several elements will be found to fall into series; a patchwork quilt is eventually formed which depicts in accurate form and in more or less complete detail the interesting and long-desired story of the migration and feeding and breeding habits of one or more species of fish. The studies of life histories of fishes of the sea are, therefore, linked with the oceanographic studies to receive brief reference in another place. W. W. Welsh, scientific assistant, has been engaged in the study and identification of the large collections of larval fishes now in the Bureau's possession. Collections were also made while he was engaged upon the *Albatross*, and just before the fiscal year closed his field studies were extended to a point on the New Jersey coast offering unusual facilities for the daily observation of fishes taken alongshore, for experiments in the hatching of such eggs as might be obtained, and for rearing the larval fishes to an advanced stage. Mr. Welsh has devised an ingenious automatic apparatus for holding pelagic fish eggs during incubation so that their development may be studied.

SARDINE OF NORTHWEST COAST.

A further inquiry into the occurrence of the pilchard or sardine, *Sardinia cœrulea*, off the coasts of Washington and Oregon was conducted during the past summer by C. L. Anderson, assistant in the Bureau. Observations and inquiries were made near the mouths of the Columbia, Siuslaw, Umpqua, and Coquille Rivers, and at Yaquina, Alsea, and Coos Bays. It is reported that some sardines enter the inside waters every summer, but that the run is extremely variable as to abundance. Mr. Anderson suggests that the presence of sardines in the bays is largely controlled by the proportion of fresh water brought into the bays by the rivers, the run being light or wanting when the salinity of the bay water is lowered. Practically none entered these bays during the past summer. While sardines may be present in the ocean beyond the bars at practically all times, as evidenced by statements of trollers and halibut fishermen and by study of the stomach contents of troll-caught salmon, yet the nature of the bars over which access to the harbors must be had and the severity of weather conditions would make it difficult to operate a regular sardine fishery. The evidence now in hand is not favorable to the establishment of an important sardine-packing industry in Northwest States.

FISHES IN RELATION TO PUBLIC HEALTH.

It is doubtful if any function of the Bureau is worth of higher public esteem than one which brings it into direct relation with improvement of the conditions of public health and makes it an effective and indispensable servant in the progressive elimination of a disease that not only produces vast economic losses by disability of laborers and employers, but year by year robs thousands of men, women, and children of energy, ambition, and happiness. The investigations of previous years not only bore abundant fruit when the Bureau could render a substantial service during war times in the protection of the health of soldiers in cantonments, but they have placed the Bureau in position to play an active and continuing part in the extensive antimalarial campaign in Southern States.

PARTICIPATION IN ANTIMALARIAL CAMPAIGN.

Responding to a request from the Surgeon General of the United States Public Health Service, Scientific Assistant S. F. Hildebrand was detailed in February to cooperate with that Service in making inspections in the Southern States and in conferring and advising with the various public health officers, Federal, State, and municipal, in the use of minnows for the destruction of the immature mosquito. As the work was extended to various points in 12 States, it was found that public health officers generally, when properly acquainted with the conditions of success of mosquito control by the use of fish, were glad to make use of a method which in many cases was both practicable and inexpensive. Many favorable reports, showing considerable savings accomplished by the use of fish under favorable conditions, have been given by sanitary engineers and others. As compared with control by oiling, the elimination of mosquitoes by the use of minnows is not only inexpensive but also relatively enduring in effect, if the bodies of water are permanent.

There appears at this time to be no other mode of mosquito control inexpensive enough to be widely applicable in rural communities where measures of drainage and oiling could be employed only at a per capita cost that renders them impracticable. The principal fish used is the common southern top minnow (*Gambusia affinis*), although the star-headed minnows (*Fundulus notatus* and *Fundulus nottii*) are being used to a limited extent. Many observations in various localities give positive demonstration of the effectiveness of Gambusia in eradication of mosquito breeding under appropriate conditions.

It is not to be inferred that mosquito control by fish is attained automatically; rather is the exercise of intelligence, knowledge, and care essential for success. It must be borne in mind, too, that as yet there have been discovered only some of the conditions of successful control. Much remains to be learned by repeated observations and experiments before the broadest use of fish as an agency for the prevention of malaria will be possible. Therefore advice and demonstration of what is now known must not be allowed to displace the plans for further investigational work. The same assistant will continue to prosecute investigations and extend practical services with particular reference to the conditions in Southern States.

FISH AND MOSQUITO STUDIES AT MOUND, LA.

Previous reports have mentioned the cooperative investigations which were being pursued with the Bureau of Entomology at the field laboratory of that Bureau at Mount, La., R. L. Barney being the Bureau's resident agent in charge. The observational and experimental work at that station was brought to a close about the middle of the fiscal year in order that the accumulated data might be compiled and a report prepared. Reports on certain phases of this investigation have been prepared, but the completion of a final report has been delayed by the loss of an assistant and by the unavoidable exactions of other duties.

MOSQUITO CONTROL IN NORTHERN WATERS.

While malaria is not prevalent in Northern States, the mosquito problem persists and exerts its ill effect upon property values, industrial productiveness, and personal efficiency. This was well illustrated when large sums of money were expended in the effort to exterminate mosquitoes in the vicinity of a large shipyard.

Prof. J. Percy Moore, of the University of Pennsylvania, as a temporary investigator for the Bureau, has been charged with certain experiments conducted in the vicinity of Philadelphia. He has also participated in investigations in the Palisades Interstate Park with reference to the control of mosquitos by the use of fish and other aquatic animals. A very gratifying degree of cooperation is extended by the officials of the park, and experiments have been started which are producing results of scientific and practical interest. Improvement of the shore conditions around one of the principal ponds of the park has already resulted in giving small fish better access to shallow coves and little cut-off pools, and this in turn has effected a material reduction in the abundance of mosquito larvæ. Subsequent examinations of the stomachs of young fishes admitted to such waters formerly teeming with mosquito larvæ have shown a large proportion of mosquito eggs, larvæ, or pupæ in the food. Other experiments are in progress.

This work is being done in connection with the cooperative investigation between the Bureau of Fisheries and the New York State College of Forestry at Syracuse, having to do with the control of mosquitoes, the elimination of blood-sucking leeches, and the development of the fish-cultural possibilities of the park. The general object is to promote favorable conditions in the park for fishing, bathing, and other forms of recreation.

EXPERIMENTAL FISH CULTURE.

Previous reports have stressed the need for fish-cultural experiment work; yet this field of endeavor remains in a condition of development that offers relatively small promise until circumstances may be changed. This is not for lack of possibilities of service to Government, State, and private fish culture, or for deficiency in facilities; the opportunity is there, but the special personnel is wanting. Fish-cultural work demands the service of specialists—those who can study systematically and continuously the functions and relations of plants, insects, crustacea, bottom conditions, fertility, form and depth of pond, etc., with reference to methods of fish culture and the productiveness of fishponds. The most the Bureau has been able to do during the year just closed has been to keep the flame of experimental fish culture burning, with the hope that provision may yet be made for its adequate conduct.

Some further results of importance have been gained in the experiments conducted at the Fisheries Biological Station, Fairport, Iowa, with catfish, buffalofish, bass, and sunfishes. Certain experiments are under way to determine the value of the use of manure or commercial fertilizers for increasing the fertility and productiveness of fishponds. Prof. C. B. Wilson at that station also continued his investigations of aquatic insects in relation to fish culture in ponds. There are shortly to be published two papers by this author on the life history and fish-cultural significance of some of the insects most commonly present in fishponds.

A paper consisting largely of compilation and analysis of published European and American data concerning the culture of fresh-water crustaceans ("shrimp," etc.) as food for fishes in hatcheries and in ponds was completed during the year by Dr. W. C. Kendall and submitted for publication. It is believed that the culture of some kinds of crustacea as food for fish would be economically feasible under certain conditions, depending much upon locality and the immediate surroundings of a particular fish-cultural plant.

A service of no little importance was rendered when Dr. Emmeline Moore, who has conducted several investigations for the Bureau, was detailed to visit some of the fish-cultural stations and advise with superintendents regarding the best use of plants in fishponds. Against what might have been assumed to be obvious handicaps, the advice of this investigator quickly established itself in the confidence and esteem of practical fish-culturists. Her work commanded such attention that her services were drafted by a State Government which could offer more favorable conditions of employment than this Bureau.

The greatest need in the fish-cultural experiment work of the Bureau is continuity and the application of persistence, skill, and judgment, and this need can be met only by the making of the special provision of personnel which the conditions may be found to warrant.

STUDIES OF DISEASES OF FISH.

Closely related to fish-cultural experimental work is the study of the diseases of fish and the conditions which occasion mortality or diminished vitality of fishes. The parasites of fishes also demand attention, not only because of their unfavorable effect upon the vitality of the fish but because the presence of parasites, even such as are not injurious, renders fish less attractive to the consumer and accordingly diminishes the market value of the fish. Diseases of fish are of real concern from an economic point of view, not only for the resulting direct losses to food supply but for the mortality of eggs, fry, or fingerling in hatcheries, which causes serious losses in efficiency and entails a substantial loss of public funds expended in fish-cultural operations. As a matter of fact, fish pathology is a broad subject for the studies of pathological and other unfavorable conditions throw light upon the various fish-cultural practices and especially upon the propriety of use and the value of the several sorts of foods employed in artificial feeding.

The routine work of the fish pathologist, Dr. Franz Schrader, included investigation into reports of fish mortalities in various parts of the country, examination of specimens sent to the Bureau for the determination of the cause of disease or death, and trips to the stations in connection with epidemics among fish or unsatisfactory conditions among fry.

An analysis of the so-called white-spot disease in fish eggs has been virtually completed. It is apparent that the ordinary occurrence of this disease finds its cause in careless handling of the eggs, be it in the course of stripping or during transportation. Bacterial agency is not primarily responsible in causing white spot as it is commonly seen during hatching operations, and European observers who have reported it seem to have had exceptional cases. Mention may be made of a still different form of the disease in Alaska, of which only superficial investigation has been made.

Work was started on the study of ovarial conditions in various fishes, especially at time of spawning. It is this phase in the various activities of fishes which bears directly on the problems of sterility, production of " glassy " ova, hardening of ovaries when retained in pens or crates, and effect of stripping. The nature of the problem makes the work on it more or less sporadic.

The troublesome question of the great mortality in hatching pike-perch eggs is under investigation at present. A visit was made to Swanton, Vt., at the time of spawning, to observe conditions in the field. In spite of the fact that the problem is an old one, it seems that no definite analysis of the morphological features of affected eggs has ever been made. Consequently the few remedial measures employed have been of little or no advantage. The essential studies are now in progress.

FISH DISEASE IN ST. LAWRENCE RIVER.

While mortality of fish in natural waters as a result of disease is not usually conspicuous, nevertheless there are occasions when such occurrences demand attention. An investigation of an epidemic among the fish in the St. Lawrence River at Ogdensburg, N. Y., was made during the first week in July, by Prof. H. S. Davis, temporary investigator. The superintendent of a New York fish hatchery had reported that large numbers of fish were dying in the ponds and also in the river.

The epidemic was at its height during the first two weeks in June and then decreased rapidly in severity. At the time of the investigation the disease had entirely disappeared from the ponds and only a few diseased fish were taken in the river. None of these appeared to be seriously affected.

The fish taken in the river showed two distinct types of lesions on the skin. On the bullheads and catfish the infected areas were very distinct, about one-half to 1 inch in diameter and bright red in color, due to the complete destruction of the epidermis, thus exposing the inflamed dermis beneath.

The diseased areas in the skin of bass and suckers had a very different appearance. They were irregular in shape and so indistinct as to attract attention only on close examination. The most marked characteristic was a faint reddish border around the scales, due to a slight extravasation of blood into the epidermis.

A microscopic examination of sections of skin from the infected areas indicates that the disease in bullheads and catfish is probably distinct from that in the bass and suckers. In the former the disease is apparently due to bacteria, which are present in enormous numbers in the disintegrating epidermis. These bacteria are not present in the lesions on bass and suckers, and the cause of this affection is at present problematic. A further report may be made.

LINSEED MEAL A CAUSE OF TROUT DISEASE.

Some time ago a peculiar disease appeared at a commercial trout hatchery in Rhode Island among yearling and 2-year-old brook trout. The fish turned black, many became blind, and large numbers died. Just previous to death an affected fish would dart rapidly about, sometimes jumping entirely out of the water. After swimming nervously in this way for a few seconds, the fish would usually turn partly on its side, remain quiescent for an instant, and then resume its former unnaturally sluggish swimming. In most cases the fish would repeat this performance several times before finally succumbing.

Dr. L. H. Almy, then fish pathologist in this Bureau, was detailed to an investigation of the trouble. It was learned that the disease had manifested itself a few weeks after the superintendent had begun feeding with a mixture of linseed meal, wheat middlings, and meat scraps, the linseed meal having been substituted for cottonseed meal previously used. When the meat scrap, with flour and salt, was used without the linseed meal, the disease was definitely checked in both adult fish and fry. Experiments planned by the fish pathologist were then undertaken at the same hatchery to ascertain which, if either, of the two meals had brought on the disease. The results, which were but recently completed for publication, proved that linseed meal was responsible for the pigment change, blindness, and death; that linseed oil in the food of trout has a slightly injurious effect; and that fish affected with linseed-meal poisoning can be brought back to a healthy condition, except for the pigment change and blindness, by a diet of some fresh-meat product.

Further experiments conducted at the White Sulphur Springs (W. Va.) hatchery of the Bureau, with the cooperation of Supt. R. K. Robinson, gave clear evidence that the pigment change, excitability, and weakened eyesight or blindness were due primarily to the prussic-acid constituent of linseed meal. The experiments indicated also that a food mixture consisting of wheat middlings and meat meal, although not injurious and apparently an acceptable food for the fish, does not compare with fresh hog lungs as a food for yearling trout.

SERIOUS DISEASE OF BUFFALOFISH.

A new bacterial disease of fresh-water fishes has been under investigation during the last two summers by Prof. H. S. Davis, temporary investigator. This disease seems to attack nearly all species of fresh-water fishes, but is especially destructive to the buffalofishes, crappies, and bluegills. It is preeminently a warm-weather disease and is apparently of little importance during the colder seasons of the year.

The disease is caused by an undescribed species of bacterium which develops only on the surface of the body and on the gills. On the body it destroys the skin, but never penetrates into the underlying muscles, while on the gills it destroys all the soft tissues. In either case the fish usually succumb within 48 to 72 hours after the appearance of the disease.

The disease does not ordinarily attack healthy or uninjured fish, but even a slight injury or the lowering of the vitality in any way renders the fish susceptible to infection. Fish are especially liable to contract the disease within a day or two after being handled.

It has been found that the disease can ordinarily be controlled by treating the fish after they have been handled with a 1 to 1000 solution of copper sulphate for two to three minutes. When properly used it has been found possible to reduce the loss from this disease from about 50 per cent to 5 per cent or less.

Studies on protozoan parasites of fishes have been continued and a paper is nearly ready for publication describing the development of the cysts and the formation of spores in a species of Myxobolus which is abundant on the gills of the buffalofishes. The early development of the myxosporidian cysts has not previously been worked out. It has been found that the young parasites reach the gills in the blood stream and become permanently fixed in the capillaries of the gills, where they develop into large saclike cysts, which may cause considerable injury to the gills. The results of studies on several other species of myxosporidian parasites, several of them new, are also nearly ready for publication.

BLACK-SPOT DISEASE OF THE BULLHEAD.

A conspicuous and unsightly disease of the common bullhead or hornpout (*Ameiurus nebulosus*) became very evident in a pond near Falmouth, Mass., in the summer of 1917. The matter having been brought to the attention of the Bureau, and no information regarding a disease of this description being available, Prof. Raymond C. Osburn was engaged as a temporary investigator for a study of the disease.

The disease takes the form of swollen, rough, tumerous, intensely black areas, affecting the skin externally ordinarily, but sometimes entering the mouth cavity and the gill chamber. The subcutaneous tissues are but little affected, the disease being confined almost entirely to the skin, and there is no evidence of spread to other parts of the body. The tumors appear to grow very slowly, but there is evidence that they are infectious, for in 1919 the percentage of infected fish taken in the pond was much greater than in 1917, and nearly all the bullheads taken showed the disease.

Careful study and experimentation proves the disease to be of bacterial origin, the causative organism being a very minute coccus, or bacterium of that general class, probably undescribed. The disease appears to be unknown to science and a widespread inquiry has brought out only the information that no one has ever observed it. The one exception in the literature is found in Thoreau's Journal, where he twice makes mention of observing such black tumors on bullheads in the Concord River and one of its branches.

With the cooperation of Dr. W. W. Browne, bacteriologist, cultures of the bacteria were made on agar mixed with the juices of the fish to produce a proper medium. Though the bacteria grow very slowly, a number of colonies were developed to a diameter of one-eighth of an inch or more in from 12 days to 2 weeks. These had the same intensely black color as the tumors. The color is produced endogenously, and the color of the tumors is due entirely to the mass of black bacteria. In older tumors a slight pressure causes the liberation of an inky black fluid, formed by the bacteria in suspension, and microscopic sections show the presence of the bacteria throughout the substance of the tumor.

Inoculations of unaffected fish from another pond were made in three ways: (1) by subcutaneous injection, (2) by abrading the skin and rubbing in the fluid taken from a tumor, and (3) by grafting portions of the tumor into the skin. Several of these developed and showed some growth in the two months that the fish were kept under observation.

It seems probable that natural infection takes place through abrasions of the skin, as the tumors are usually located on the fins and lips where such abrasions would more naturally occur accidentally. The habits of the bullheads in schooling together render this mode of transfer easy.

As to the fatality of the disease we have no information. Certainly it is not rapidly fatal, for specimens with well developed tumors were kept alive in aquaria in the laboratory for six weeks without showing any appreciable change other than some slight growth in area and thickness of the tumor. It would thus appear that no active systemic poison or toxin is formed by the bacteria. There is, however, a tendency for the tumors to become fungused with *Saprolegnia*, a water mold, which would no doubt cause death in time if the tumor did not. While dead catfish have not been observed about the pond, the shores are such that they would not readily be noticed. No other species of fish in the pond showed any indication of the tumors, and the probability is that the disease is specific for the bullhead.

GENERAL STUDY OF PARASITES OF FISHES.

Systematic studies of the parasites of fishes are important for several reasons. While the presence of some parasites is a normal condition in fishes as well as in domestic animals, such as cattle, sheep, and poultry, they may upon occasion become so numerous as to cause the weakening or death of the animal infected. When not leading to death they may yet so affect the condition or appearance of the fish as to render them unacceptable to the housekeeper, which means the loss of the fish as a possible article of food. In cases of this kind, and they occur not infrequently, one can not approach the question of cause or remedy or give proper advice to the public unless there is a background of knowledge concerning the normal degree of prevalence of different kinds of parasites in the several species of fish. It is economically necessary, then, that observations of parasites should be made systematically and a large body of evidence obtained. Dr. Edwin Linton's studies in recent seasons have covered about 40 species of fish in the region of Woods Hole, Mass. Attention is being devoted now particularly to the round worms (nematodes). The fear has been felt that round worms, which occur on the viscera of certain fish and not normally in the edible parts of the fish, might during storage of the dead fish burrow into the flesh of the fish and thereby become objectionable. The experiments conducted indicate that the worms do not penetrate the flesh or become attached to it in such a way as not to be removable by the ordinary process of washing.

In this connection reference may be made to the studies of the food of young fishes conducted by the same investigator and applying to 18 species of fish of the Woods Hole region.

THE OYSTER.

The eastern oyster supports the most valuable fishery possessed by any country and based upon a single species; but, important as the oyster industry is in contribution to food supply as well as in its part in the economic life of the Nation, its future can be viewed only with keen anxiety. For some years the industry has been manifestly declining. In past times its chief seats have been on the south shores of New England and New York and in the Chesapeake Bay. During a long period the yield of the Chesapeake has gradually fallen away because of the depletion of natural beds and the misfortunes which have attended all attempts to establish a proper legal basis for the development of a great oyster farming industry. In waters of the vicinity of Long Island oyster farming has long been established on a large scale, but in recent years, and because of conditions which are not yet fully understood, there has been a notable failure of the setting of seed. The planting industry now depends to a very considerable extent upon the importation of seed oysters from distant points; and the expense and the uncertainties are such that leases of oyster bottoms are continually being given up, with consequent loss of revenue to States, as well as diminution in the production of a valuable article of food. The problem of the failure of set has therefore become one of great concern to State Governments as well as to the Nation. It is, however, one of great complexity and may well receive the best attention of all concerned.

There are oyster industries in Pacific Coast States which are now of no little importance and which may have much greater significance in future. It is, therefore, a cause for regret that the limitations of personnel and appropriations have prevented the Bureau from giving to these the attention which they merit.

OYSTER INVESTIGATIONS IN LONG ISLAND SOUND.

At the temporary field laboratory at Milford, Conn., Dr. E. P. Churchill and J. S. Gutsell, scientific assistants, continued the investigations relative to the propagation of oysters. R. V. Truitt, temporary assistant in oyster studies, was engaged in that laboratory for a part of the summer, but spent the greater part of the season in a preliminary reconnoissance of the Chesapeake Bay with reference to oyster culture. The conditions prevailing in the vicinity of Milford were in contrast to those in Great South Bay, Long Island, mentioned on another page. Water samples (usually 50 gallons at a time) were collected in various localities from June 16 to September 10, and, although 215 such samples were examined, only 303 oyster larvæ in all were encountered. Four of the samples yielded 250 of these larvæ, 23 other samples gave small numbers (from 1 to 8), and 188 were barren. (In Great South Bay, on the other hand, several thousand larvæ were sometimes found in one sample.) There being no larvæ, there was, of course, no set.

The virtual absence of free-swimming oyster larvæ from the Milford region is believed to be due to the low temperature of the water, which may have prevented either the fertilization of the eggs or the development of those that were fertilized. The larvæ found were all of the smallest sizes. The bottom temperature, where the water was 20 feet or more in depth, registered as high as 70° F. on only one occasion. For the remainder of the time during the usual spawning season of oysters, it ranged from 65 to 69.5° F., being usually about 68. Oysters in this region are found to begin spawning at a temperature between 68 and 70°. It was observed that oysters in the deeper water did not spawn until about the middle of August, the process continuing slowly and in patches over the beds during the rest of the month. Some of the oysters apparently gave out no spawn at all.

While the shallower water of the coves and harbors warmed up earlier than that outside, and the oysters there spawned earlier, the incoming tide was so cold this season as materially to affect the inside waters, and oyster eggs or larvæ carried from the shallow waters doubtless perished in the cold water outside. In any event, and corresponding with the absence of free-swimming larvæ, as noted, no set of oysters was found or reported anywhere in Long Island Sound.

As emphasized in the report covering the season of 1918, the best evidence obtainable indicates that in former years the set was produced in favorable seasons by natural inshore beds of oysters in warm waters where spawning occurred relatively early. All are agreed that such beds are largely exhausted. The result of the Bureau's investigations tends to substantiate the view that the securing of set in commercial quantities on planted beds, even during favorable seasons, is contingent upon the restoration of the natural beds in inshore waters. Acting upon suggestions to this effect previously offered by the Bureau, the State of Connecticut has appropriated $10,000 for building up the spawning beds, and the results of this practical experiment may be awaited with interest.

WATER POLLUTION AS AFFECTING GROWTH AND BREEDING OF OYSTERS.

It is the inshore waters which are most directly affected by pollution from sewage and industrial wastes, but indirectly the pollution may have a still more significant economic effect on offshore beds even though none of the polluting substances actually touch these beds. It must be remembered that oyster larvæ are free-swimming and may be borne by currents for some distances. The beds in deeper waters are not necessarily self-perpetuative, but may well have been reseeded in former times by set arising from larvæ borne in the waters from breeding oysters in shallow waters. Our observations have indicated, first, that successful propagation of oysters in the Long Island region is dependent upon early spawning, which allows time for development to an advanced and resistant stage before cool weather; second, that this in normal years may occur only in the warmer waters; and thirdly, that spawning beds in shallow waters have virtually disappeared, partly in consequence of excessive fishery, but principally because the excessive pollutions have led to the general abandonment of such areas for oyster planting.

Consequently, in approaching the vital problems of the oyster industry of this region it is impossible to escape attack upon the question of pollutions. Here both chemical and biological problems are involved. The analytical chemist ascertains what substances of possible toxic nature are discharged into the waters; the biologist must determine by experiment the effects of such substances upon the existence and growth of oysters and their efficiency in breeding, and must find the precise degree of concentration which is injurious; finally, the engineering chemist must discover how such substances may be either eliminated altogether from effluents or at least kept within the bounds of safety as indicated by the biologist.

Such investigations by analysis and experiment are now being prosecuted by the Bureau of Fisheries in cooperation with the Bureau of Chemistry, and probably something of a more definite and satisfactory nature may be embraced in a subsequent report.

EFFECTS OF LOWERED OXYGEN SUPPLY UPON OYSTERS.

While the investigation of the subject of pollution as affecting oysters is one of some complexity, it is known that one of the most immediate effects of pollution, generally speaking, is the reduction of the oxygen content in water. During the summer of 1919 an investigation was conducted by Dr. P. H. Mitchell, director of the Fisheries Biological Station at Woods Hole, Mass., to determine the effects of lowered oxygen content on the survival of oysters, the work being done in both field and laboratory.

Observations in the field were based upon a series of small plants of oysters in Seekonk River, a tidal estuary at Providence, R. I., and in Providence River, below the mouth of Seekonk River. Determinations of the dissolved oxygen in the water at the locations selected were made at various times and under various tidal and weather conditions. The results indicated a substantial mortality of oysters where the average dissolved oxygen content was 26 per cent of saturation or less and nearly all oysters died within a period of 50 days where the percentage of saturation was less than 12.

Observations in the laboratory were conducted by keeping oysters in small containers furnished with sea water of varying oxygen content and subject to as definite control as possible. The results indicated that the minimum oxygen content of water that will sustain oysters during a period of one month is between 25 and 33 per cent of saturation. Further experiments are planned to determine the effect of lowered oxygen supply upon the propagation of the surviving oysters.

Another series of experiments have substantiated the earlier findings of copper storage as the explanation of the appearance of a bluish-green color, and recent results point to a possible significant relation between the development of the undesirable blue-green spots and the deprivation of oxygen.

OYSTER INVESTIGATIONS IN GREAT SOUTH BAY.

Dr. Churchill and Mr. Gutsell completed a report upon the spawning of oysters and setting of oyster larvæ in Great South Bay, Long Island. The conditions in this shallow bay offer a contrast to those of the deeper water of Long Island Sound, where low temperatures had prevailed and a failure of set occurred.

In Great South Bay the spawning season extended from about June 5 to July 17, the heaviest spawning occurring July 2 to 6, and the greatest abundance of larvæ being found from July 7 to 11. Spawning began about the time the water temperature reached 70° F., and proceeded briskly while it ranged from 70 to 76°, but slowed down or ceased when the temperature fell to 70 and 68°. When the water temperature rose to 75° and above, about July 2 to 6, the bulk of the spawn was thrown out within the course of two or three days. The approximate length of the free-swimming period was 12 to 14 days. Considerable mortality of the free-swimming larvæ followed a sudden lowering of water temperature or the severe agitation of the water by storms.

The investigation served to throw considerable light on the proper time of planting cultch and the best location of plants for catching a set.

OYSTER INVESTIGATIONS IN LITTLE EGG HARBOR, N. J.

Dr. T. C. Nelson, assistant biologist of the New Jersey Agricultural Experiment Station, completed during 1919 a six months' study of the food and feeding of oysters. While this work, carried on at Edge Cove, Tuckerton, N. J., was primarily State work, yet, since its beginning and continuity were made possible by the cooperation of this Bureau, a summarized account of the results attained is not out of place in this connection.

Studies of the food of oysters were conducted from a floating laboratory anchored directly over the oysters, making it possible to keep a continuous record of the temperature, density, and rate of flow of water, parallel with examination of the food content of oysters.

The results of the microscopic analyses indicate that minute animals may play an important part in the oyster's nutrition. Copepods, nauplius larvæ, ostracods, gastropod and bivalve veligers, round worms, rotifers, and protozoa were found in great numbers. As a typical case, the contents of the stomach of one oyster showed over 4,000 nauplius larvæ and 60 large copepods, besides many protozoans. That these crustaceans are digested was shown by the large number of skeletal parts found in the stomach and intestine.

To study the rate of growth, 1,000 oysters were tagged, weighed, measured, and put out on a fixed platform 1 foot above the bottom. In 130 days these oysters grew in some instances as much as 3 centimeters (1.2 inches), while the increase in weight for oysters 1 and 2 years old was from 40 to 60 per cent. The duration of feeding in the oyster was determined by levers led from the shell of an oyster lying on the bottom to an electrical recording instrument (chimograph) above. The oyster, under natural conditions, continued to feed from 19 to 20 hours out of every 24.

One result of the investigation of the oyster's food has been the demonstration of the large part played by organisms growing on the oyster's shell. On the shell of one oyster 5 inches long were found diatoms in number computed to be over 56,000,000. Oysters covered with external growths may be partly independent of the actual food content of the water flowing over them.

OYSTERS IN VIRGINIA WATERS ENDANGERED BY FUEL OIL.

In the early part of 1919 the escapement of fuel oil upon the waters of Hampton Roads so affected the condition and flavor of planted oysters as to make them unmarketable for a time and to cause substantial financial losses. In the latter part of 1919, in response to reports that fuel oil, presumably discharged from oil tankers, was again threatening the oyster beds in Hampton Roads, the Bureau detailed an assistant to cooperate with the Navy Department in an investigation of the matter. After consultation with the captain of the port and several oyster planters, and after inspection of the water of Hampton Roads, it was found that at that time oil was not being discharged into the waters in sufficient quantities to menace the oysters. Strict orders forbidding the practice had been issued some time previous by the captain of the port, and these were apparently being enforced in such a way as to obviate injury to the oysters.

There have, however, been several subsequent complaints, and, after repeated attempts to render assistance through investigation, the Bureau found it advisable to refer the matter to the Department of Justice, which has taken appropriate action for the institution of legal proceedings upon complaints properly filed with the local United States attorney. It is understood that some convictions have been secured.

OYSTER INVESTIGATION IN THE YORK RIVER.

The investigation of the poor condition of oysters prevailing in a section of the York River, Va., since 1914, was brought to a conclusion during the year. The oysters have been consistently poor and watery and very generally affected with blue-green spots. Examination of the food content of the water revealed a condition of relative sterility. A special endeavor was made to determine the validity of the local belief that the trouble originated from toxic chemicals discharged from an industrial plant located on the banks of the river. With the cooperation of the Bureau of Chemistry, observations were made at intervals over a period of nearly a year, yet nothing was found in the effluents from the mill which could materially affect the oyster beds in any direct way. The trouble appears to rest upon the deficiency of food supply, but neither the biological nor the chemical studies served to fix a specific cause for the lack of food. The condition is presumed to result from natural causes which are at present obscure and therefore beyond control.

REPORT ON THE OYSTER INDUSTRY.

In the course of the year there was completed and sent to press a report comprising for public information a full account of the present condition and practices of the eastern oyster industry, both as it is based upon the exploitation of public oyster beds and as it manifests itself in the various phases of commercial oyster culture.[a] The report is published in response to the frequent demands upon the Bureau for information of the character furnished by it.

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[a] Churchill, E. P., jr.: The Oyster and the Oyster Industry of the Atlantic and Gulf Coasts. Appendix VIII, Report, U. S. Commissioner of Fisheries, 1919, 51 pp. Washington, 1920.

FRESH-WATER MUSSELS.

The Bureau continued the propagation of fresh-water mussels and investigation of problems affecting the mussel industries. The number of glochidia infected upon fish and liberated in the public waters was substantially greater than in the preceding year, and the unit cost per thousand correspondingly lower. The results of artificial propagation are detailed in another report.[a]

EXPERIMENTAL WORK.

Notable results were obtained in the experiments conducted at the Fairport station in rearing young mussels. The methods of artificial propagation, as regularly practiced, consist in liberating the fish immediately after infection, so that cultural operations are not involved. In the effort to improve upon the established practices, experiments have been conducted during several seasons in retaining infected fish during a period of two or three weeks, until the juvenile mussels are liberated, and then holding the young mussels, which at first are of microscopic dimensions, until they have attained a size (say one-half an inch in length) permitting of their being handled with convenience and planted deliberately upon bottoms which are known to be suitable. Simple as the task is in the stating, peculiar difficulties are encountered, and its accomplishment had baffled all previous attempts in this country and elsewhere. Before the past year a measurable degree of success had been attained at Fairport with one species of mussel (the Lake Pepin mucket). During the summer of 1919, the experiments conducted by Dr. F. H. Reuling led to the rearing of two additional species (yellow sand-shell and river mucket) in considerable quantities in small troughs supplied with naturally clarified river water.

Experiments having a somewhat similar object were conducted in Lake Pepin by Roy S. Corwin, scientific assistant. Here young mussels originating from artificial infections were reared in considerable quantities within inclosures on the bottom of the lake in relatively shallow water. Other experiments conducted at this place gave indication that glochidia carried over in the marsupia from the preceding year endured a shorter period of parasitism than those taken from the marsupia in the same season in which the eggs were deposited.

Dr. L. B. Arey, of Northwestern University Medical School, investigated the relations of glochidia to host as regards attachment and encystment, and the results of his investigations have been submitted for publication in another place.

PROTECTION OF MUSSELS.

In January, 1920, at La Crosse, Wis., the Bureau participated with officers of the Wisconsin Conservation Commission and the Minnesota Fish and Game Commission and other interested persons in a conference relative to the protection of fresh-water mussels. Acting upon the authority provided by recent concurrent legislation, it was determined to close against commercial shelling for a period of five years certain sections of the Mississippi River bordering the two States represented in the conference. The purpose is to allow opportunity for natural recuperation of the beds and to create favorable conditions for the artificial propagation of mussels.

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[a] Smith, Hugh M.: Report, U. S. Commissioner of Fisheries, 1920. Washington, 1920.

After several years of earnest effort by various persons and agencies, in which the Bureau of Fisheries has played a leading part, concurrent legislation for the protection of fresh-water mussels has been enacted in the four States which control the principal mussel-producing portions of the Mississippi River. It is hoped that the practical steps now being taken to give effect to that legislation will result in a marked recuperation of mussel beds which have been exhausted or seriously depleted.

PUBLICATION OF REPORTS.

In the course of the fiscal year there has appeared a document of the Bureau describing in detail the commercial fresh-water mussels, the implements and practices of the mussel fishery, and the machinery and methods of manufacture of buttons from the shells.[a] There has also been completed and submitted for publication a general account of the natural history and propagation of the mussels.[b] These papers are issued in response to a regular demand for the varied information contained in them, and with a view to disseminating such knowledge of the resources and industries and the conditions of their perpetuation as will stimulate the adoption of measures and practices whereby unnecessary waste may be avoided and the future, as well as the present, may be served.

OCEANOGRAPHIC AND LIMNOLOGICAL STUDIES.

WORK OF THE ALBATROSS.

The oceanographic and fishery work of the steamer *Albatross* had been entirely abandoned for the period of the war, and the vessel was engaged exclusively in the service of the Navy Department. Some changes in the vessel had naturally been made to adapt her to military service, but, before the return of the vessel, that department restored such features of plan and equipment as were desired by the Bureau. At the same time the Bureau, at its own expense, developed the fixed equipment of the vessel, so that she is now better fitted than ever before for fishing trials. The new equipment consists principally of a more powerful steam winch and other necessary fixtures for operating fishing trawls. There have also been purchased and placed upon the boat a series of otter trawls and other fishing gear.

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[a] Coker, R. E.: Fresh-Water Mussels and Mussel Industries of the United States. Bulletin, U. S. Bureau of Fisheries, Vol. XXXVI, 1917–18, pp. 11–89. Washington, 1919.

[b] Coker, R. E., Shira, A. F., Clark, H. Walton, and Howard, A. D.: Natural History and Propagation of Fresh-Water Mussels. Bulletin, U. S. Bureau of Fisheries, Vol. XXXVII, 1919–20. In press.

The greatest obstacle to the oceanographic work of the vessel has been the impossibility up to the present time of maintaining an adequate supply of dependable reversing thermometers for taking temperatures at varying depths. No American manufacturer is yet in position to furnish thermometers that meet the precise requirements for deep-sea work, and it is only after considerable delay that a limited number of satisfactory instruments have been obtained in London and Copenhagen.

The operations of the *Albatross* during the fiscal year covered two principal cruises. The first, beginning off Cape Henry at the close of October, 1919, extended as far as the Yucatan Channel in the south. The investigations aboard the vessel were directed by Mr. W. W. Welsh, scientific assistant. Biological and physical oceanographic stations were occupied on four sections across the Gulf Stream between Cape Henry and Key West; across Florida Strait, between Key West and Habana; from Habana to Cape San Antonio, at the western end of Cuba; across the Yucatan Channel to Cape Catoche; and from Cape Catoche to Dry Tortugas. Considering that the ship had been but recently placed in commission in the Fisheries Service, after having done duty in the Navy for two years, that much of her gear was new, and that practically her entire personnel was inexperienced in work of this character, her performance was regarded as satisfactory. The work is intended as a contribution to a scientific basis for fishery investigations by the ship during the next two years.

On February 18, after having undergone repairs at Baltimore, the *Albatross* sailed from Norfolk for Boston, to make headquarters for fishery and oceanographic investigations in the Gulf of Maine. On the trip to Boston she made three hauls with a 60-foot otter trawl in the vicinity of the 100-fathom curve, with the purpose of determining the occurrence of tilefish and other ground fish off the middle Atlantic coast. The results were negative. She also occupied a series of hydrographic stations on a line across Georges Bank. The vessel was engaged in the investigation of the Gulf of Maine until the latter part of April, after which she prosecuted a search for spawning haddock in Massachusetts Bay and returned to Baltimore to lay up for necessary repairs. This work was in continuation of investigations begun in the same waters by the *Grampus* in 1912, and is under the direction of Dr. H. B. Bigelow, of the Museum of Comparative Zoology, Cambridge.

The hydrographic and dredging records obtained on those cruises with all previous unpublished records of the vessel have been prepared for printing and will appear at an early time. The recent work of the *Albatross* in the Atlantic Ocean and Gulf of Mexico has been guided by the deputy commissioner, Dr. H. F. Moore, who will be able to coordinate many of the activities of this vessel with the observational work done under the International Ice Patrol Board, of which he is a member. Prior to the fall of 1919 the *Albatross* had not worked in the Atlantic since 1887.

SURVEY IN CHESAPEAKE BAY.

The biological and physical examination of the Chesapeake Bay, begun some years ago and interrupted by the conditions of war, has been resumed under the immediate supervision of Dr. R. P. Cowles as temporary investigator. The chief purpose is to determine the normal biological and physical conditions throughout the year. This done, there would then be normal data at hand from which to determine the abnormal conditions which bring about such serious mortalities of fish or oysters as have occurred in previous years. The survey should reveal all that is possible regarding the movements of layers of water of different densities, different temperatures, and different fish-food values, and should indirectly throw light upon the migrations of fish and crabs into or about the Bay. Special attention will be given to the "deep holes" and to the alleged barren bottoms at the mouths of rivers, and, through the collection of bottom deposits and the collaboration of the United States Geological Survey, information of value to geologists will be secured. In general the purpose is to gather as much as possible of the data which are essential for the conservation and development of the fisheries of this important body of water.

BIOLOGICAL AND PHYSICAL STUDIES OF INLAND LAKES.

The Bureau has continued to cooperate with the Wisconsin Biological and Natural History Survey in the studies of the fundamental conditions of inland lakes. The principal burden of these investigations is borne by the State, but it is not out of place to present here a brief statement of the status of the work, based upon a progress report submitted by President E. A. Birge and Mr. Chancey Juday. Bulletins on the plankton algæ, on gravimetric and chemical analyses of the plankton of the lakes in the vicinity of Madison, and on the bottom fauna in deeper water of Lake Mendota are now substantially or entirely completed. These reports comprise descriptions of many of the plankton elements and other units of fish-food supply, data regarding chemical composition (the basis of food value), and measures and computations of the quantities of the crops of organisms which maintain the productiveness of lakes in fish. Studies of the bacteria of Lake Mendota are in progress.

MISCELLANEOUS STUDIES.

REDDENING OF SALT FISH.

The salt-fish industry of the United States suffers a large annual loss as a result of the salt fish developing a red coloration when stored under moist conditions. Investigations conducted for the Bureau by Dr. W. W. Browne indicate that the development of the red coloration is due to the growth of two microorganisms, whose probable origin is the sea salt in which the fish are cured. This coloration may vary from a pale pink to a deep crimson. The pale pink coloration is produced as a result of the growth of a spirochete and the deep red by a bacillus form; these two organisms may, however, grow in such close harmony that the pigmentation may vary from a pale pink to red. It was formerly thought that the varied pigmentation was due to varied dilutions of the red pigment. The separation of the two organisms is very difficult owing to this close union.

The optimum concentration of salt for the growth of these microorganisms seems to be saturation. They grow well on heavily salted fish, brine, salt piles, and fish agar saturated with salt. No growth appears on media containing less than 15 per cent salt, by weight. Due to their sensitiveness to changes in density, staining of these bacteria for microscopical examination is very difficult. The morphology or shape of the organisms depends upon the concentration of salt in the medium, varying from the largest form (14–16 micra), found in heavily saturated media, to the spherical form (2 micra diameter) in media of 16 per cent concentration. Likewise all intermediate forms are present in the concentrations between 15 per cent and saturation. The amount, character, and pigmentation of the colonial does not seem to be affected by the varying changes in the concentration of salt.

The most favorable temperature for the growth of both the spirochete and the bacillus is between 50 and 60° C., indicating the salt lagoons of the Tropics as the probable source of the infection. Sunlight is not germicidal to these organisms, and this also points to their tropical origin, where the pigmentation is required as a protection against the bright sunlight; ordinary bacteria are killed by 10 minutes' exposure to bright sunlight. Influenced by age, by the accumulation of their own metabolic products, and particularly by low temperatures, both organisms suffer a temporary loss of pigmentation. During this loss the formation of the so-called "coccoid bodies" is noted in the pink spirochete. No change in the shape of the bacillus during the absence of pigment has been noted. After transplantation, both pigmentation and the regular vegetative form is resumed.

All results indicate that the causative agents of this troublesome and costly coloration have been discovered and that their original source is the solar evaporated sea salt in which the fish are cured. Both European and American sea salts are infected. Mined or domestic salt seems to be free of their presence. Any method devised for the elimination of this reddening of salted fish must be based upon either the proper disinfection of the sea salt before use or the substitution of mined or domestic salt which is free of infection. In either case a thorough disinfection of the salt fish plants and equipment is essential, since at the present time all are highly infected. It would be useless to dump sterilized salt or even mined salt into a highly infected plant or to bring unsterilized salt into a thoroughly disinfected plant.

With this knowledge of the life history of the organisms, the conditions essential for their growth, and the sources of infection, the Bureau already has under way experiments to determine the best and most practical means of eradicating a most troublesome factor from the salt-fish industry. During the entire series of experiments the Bureau has had the hearty cooperation of the salt-fish industries.

LOCATION OF FISH FROM AIRCRAFT.

In July, 1919, in cooperation with the Naval Aviation Service, W. W. Welsh, a scientific assistant in this Bureau with naval experience, made a flight at Cape May, N. J., to determine the possibilities of scouting for schooling fish with the aid of aircraft. The results of this trial were very favorable, but, since the development of the method and its application to the fisheries lies properly within the sphere of activity of another office of the Bureau, the further history of the matter does not pertain to this report.

JELLY FROM SEAWEEDS.

During last summer Prof. Irving A. Field conducted for the Bureau, in connection with the Woods Hole laboratory, investigations concerning the feasibility of deriving from marine algæ a gelatin suitable for use in the preservation of fish. The experiments of commercial packers have previously indicated that animal gelatins liquefied at such low temperatures that they could not be employed for this purpose. The jelly is not ordinarily used as a preservative in a strict sense, but as a medium in which the preserved fish are held and prevented from breaking to pieces in shipment.

Of all the algæ of the New England coast employed in the investigation only the Irish moss (*Chondrus crispus*) yielded gelatin—or, more correctly, gelose—in commercial quantities. It was found that Irish moss contained 79 per cent water and that the desiccated material was approximately 65 per cent gelose. The gelatinous extract from Irish moss is commonly known as "caragenin," but Dr. Field's experiments indicate that it is closely comparable to agar-agar. Agar-agar is made in Japan from another seaweed, *Gelidium corneum*, which is found to some extent on our Pacific coast and, in limited quantities, on the Atlantic coast.

The investigation developed provisional methods of preparation of caragenin, and a series of tests showed that 1¼ grams of the dried extract added to a 14-ounce can of fish was sufficient to form a firm jelly that prevented such soft fish as whiting and herring from breaking to pieces when subjected to the rough treatment of being transported 400 miles in the back of an automobile. The jelly in no way impaired the condition or the flavor of the fish. The preparation of the jelly in a form satisfactory for commercial uses remains to be investigated to a further stage. Other problems arising from the investigation relate to the decolorizing and purification of the jelly to adapt it for other possible uses. Experiments will also be made with other seaweeds from both coasts of the United States.

UTILIZATION OF FRESH-WATER TURTLES.

A relatively unutilized food resource is found in the several species of turtles of our fresh-water streams and lakes, notwithstanding that their near relative, the diamond-back terrapin of the sea coast (not to mention the highly prized green turtle of the ocean) is the greatest delicacy of the fish markets. In the endeavor to direct proper attention to this source of meat supply and to furnish the information requested by many correspondents, assistants were designated to investigate market and fishery conditions, particularly in the Mississippi Basin. The report by H. Walton Clark, scientific assistant, and J. B. Southall, shell expert, comprises information regarding the distribution and habits of the most useful species, an account of the seasons and methods of capture and marketing, and data concerning the preparation of the meats for use as food.[a] The report will undoubtedly serve a useful purpose in promoting the utilization of an available source of food and thereby will contribute to the prevention of waste of the Nation's food supply.

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[a] Clark, H. Walton, and John B. Southall. Fresh-Water Turtles: A Source of Meat Supply. Appendix VII, Report, U. S. Commissioner of Fisheries, 1919, 20 pp. Washington, 1920.

UTILIZATION OF FROGS.

The daily correspondence of the Bureau has indicated for a long time the widespread interest in frogs, their utilization and propagation, and their elimination from localities where they are not desired. Nevertheless the Bureau has not yet felt justified in diverting to experiments in frog culture facilities which are required for other useful purposes, especially in view of the extensive natural resources in frogs which are not now fully availed of. It has been deemed distinctly worth while, however, to acquire as full knowledge as possible of the useful species, their habits, conditions of life, breeding, life history, food, and enemies, as well as of the methods of capture employed. The report by Dr. A. H. Wright, temporary investigator, went to press during the year.[a] With this handbook the frog fisher or the prospective frog-culturist may readily identify the frogs in any stage—eggs, larvæ, tadpoles, or adults—and may be guided in the selection of environments for fishing or propagation.

THE BIOLOGICAL LABORATORIES.

The Navy Department having withdrawn from the Woods Hole (Mass.) station, the laboratory was reopened at the beginning of the fiscal year, with Dr. P. H. Mitchell as director. With a limited staff, investigations were pursued with reference to oysters (p. 21), gelatin from seaweeds (p. 29), the reddening of salt fish (p. 27), and the food and the parasites of fishes (pp. 18 and 19), the results of which have previously been indicated. Some experiments were also conducted by Dr. F. E. Chidester to determine some of the factors which influence the migrations of fishes and the behavior of fish in presence of certain chemicals. A miniature river system was employed, in which the fish were given a choice between two tributaries having water supply of different nature or current of different rates. It was found that the behavior of the fish varied according to season or condition of the animal, and particularly according to the rate of flow of the water; but—given a proper condition of stream flow, the first were repelled by some salts and attracted by others. The results will be published after further experiments are made.

The Beaufort (N. C.) laboratory, after occupancy by the Navy, since January, 1918, was turned over to the Bureau of Fisheries shortly after the beginning of the fiscal year. Since that time many necessary repairs and renewals have been made both by the Navy Department and by this Bureau. The date of the station's return prevented its opening on the usual scale for investigational work during the summer and fall. Small salaries have tended to making the personnel changeable and have prohibited the beginning of any broad investigational project. O. W. Hyman served as acting director during the summer and until the director, R. L. Barney, who was still absent on detail, could be returned to duty at the station. The director and three assistants, each of the latter for short periods, have devoted themselves to the preparation of a comprehensive report of the results of the experimental work on the propagation of the diamond-back terrapin. Attention has been given also to a study of a bacterial disease of the winter-fed yearling terrapin of the experimental broods. One temporary investigator has been engaged in the study of the life histories of crabs of the Beaufort region.

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[a] Wright, A. H. Frogs: Their Natural and Utilization. Appendix VI, Report, U. S. Commissioner of Fisheries, 1919, 44 pp. Washington, 1920.

At the Fairport (Iowa) biological station (A. F. Shira, director) a notable event of the year was the construction of the new laboratory authorized by the Congress to replace the former building destroyed by fire in December, 1917. The building which was nearly ready for occupancy at the close of the fiscal year is virtually fireproof, creditable in appearance, and admirably adapted for the purposes to be served. It contains laboratory space for all needs that are expected to develop in the near future. In all, $95,000 has been appropriated for construction and equipment, and, as the building cost about $83,000, there remained approximately $12,000 available for furniture and equipment, including the purchase of the necessary scientific apparatus and books. Before the close of the year sufficient equipment had been ordered to make it possible to occupy and use the building as soon as it could be accepted from the contractors.

The experimental work of the Fairport station in relation to fish culture (p. 13) and mussels (p. 24), the service in promoting the protection of mussels (p. 24), and the investigation of the utilization of turtles (p. 29) have been referred to. Field investigations were conducted in western Montana, where scattering mussels were found in the Musselshell River, though not in quantities permitting of commercial exploitation. Experiments were made in transplanting mussels to eastern waters. Progress was made in reporting upon the biological survey of Andalusia Chute, and an examination of portions of Lake Keokuk was undertaken. Studies, which were conducted at the station and not hitherto mentioned in this report, relate to the food of mussels (by H. W. Clark) and the acanthocephalid parasites of fishes (by Dr. H. J. Van Cleave).

At Key West, Fla. (S. F. Hildebrand, director), attention was devoted to construction and equipment of the biological station provided for that place. Owing to the lack of funds and the high cost and scarcity of material and labor only one permanent structure, a concrete water tower containing three tanks, was built. A small electric-light plant and two pumping units, one for salt and one for fresh water, were installed. Nets, glassware, and microscopes were added to the station's equipment for conducting investigations. The grounds were graded in part and improved by planting, and a metal flag staff was erected at a central and prominent point on the reservation.

The station was visited by a severe hurricane on September 9 and 10 which worked some damage to buildings and grounds and occasioned some expense in repairs to buildings and in regrading of grounds. It was not noticed that the storm had any effect upon the local fisheries, except that so many of the boats in the vicinity were wrecked that few fishermen were able to continue their occupation for some time; those that were able to go out obtained the usual catches.

Many collecting trips were made and observations gathered regarding the life histories and habits of fishes. An attempt was made to build up a representative series of the local fish fauna for future reference. Several species were obtained which had not hitherto been recorded from the vicinity of Key West. Observations of the markets were regularly made and reported, and it was found that, regardless of the handicap occasioned by the hurricane which destroyed or damaged many fishing boats, the catch of fish during the fiscal year 1920 was greater than during the preceding year, the increase applying particularly to kingfish and Spanish mackerel.

Investigation of the spawning of the mullet, *Mugil cephalus*, was made in the vicinity of the Ten Thousand Islands in December and January, but, although both nearly ripe and spent fish were found in course of the investigation, definite information of the time, place, and manner of spawning was not forthcoming. Observations upon the spiny lobster were continued as long as was practicable.

Examination was made of the quahaug or hard-clam beds in the vicinity of the Ten Thousand Islands and many data were obtained in regard to the abundance of clams, the manner and methods of catching them, and their commercial utilization. The investigation revealed the presence of such extensive resources in clams in this vicinity that an economic circular was prepared and issued by the Bureau to the trade.[a]

All positions connected with the Key West station, except that of engineer, became vacant in the course of the year, and the scientific work was therefore brought to a close in February. Since that time the station has remained inactive and in the charge of the engineer as caretaker. Regular incumbents for the positions at this station, including that of superintendent, have been unobtainable through the Civil Service Commission.

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[a] Clam Resources of the Ten Thousand Islands, Fla. Economic Circular 46, 5 pp. Washington, 1920.

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